SEISMOTECTONIC ANALYSIS IN KEFALLINIA-LEFKAS (GREECE)

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A B S T R A C T

Seismological data collected in the north-western part of Greece, for a period of two months, during the summer of 1989, are presented and analyzed in order to discuss the seismotectonic regime in Kefallinia-Lefkas Ionian islands. The distribution of the epicenters is located between 0 and 40 km and mainly concentrated in three clusters: two in the northern part of Kefallinia and one in the western part of Lefkas. In the northern part of Kefallinia, the two observed clusters are separated by a 'gap' of about 3 km. The focal mechanisms constrained for the first cluster, represent two completely different solutions: normal or reverse faults. Both cases could be related to the large earthquakes occurred in the surrounding area. The second cluster represents more homogeneous reverse fault plane solutions with a right lateral motion. The third cluster in western Lefkas represents also homogeneous reverse fault plane solutions with a right lateral motion.

ΣΕΙΣΜΟΤΕΚΤΟΝΙΚΗ ΑΝΑΛΥΣΗ ΠΕΡΙΟΧΗΣ ΚΕΦΑΛΛΗΝΙΑΣ-ΛΕΥΚΑΔΑΣ (ΔΥΤΙΚΗ ΕΛΛΑΔΑ)

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Π Ε Ρ Ι Λ Η Ψ Η

Το καλοκαίρι του 1989, στα πλαίσια ερευνητικού προγράμματος της ΕΟΚ και με τη συνεργασία των πανεπιστημίων Αθήνας, Θεσσαλονίκης και Γκρενόμπλ (Γαλλίας),ένα σεισμολογικό δίκτυο 56 σταθμών εγκαταστάθηκε στην περιοχή της Βόρειας και Δυτικής Ελλάδας για ένα χρονικό διάστημα δύο μηνών, προκειμένου να μελετηθεί η σεισμικότητα της περιοχής αυτής.

Στη μελέτη αυτή παρουσιάζονται τα αποτελέσματα της σεισμοτεκτονικής ανάλυσης της περιοχής Κεφαλληνίας-Λευκάδας. Η σεισμικότητα της περιοχής χαρακτηρίζεται από τρεις ομάδες. Οι δύο από αυτές προσδιορίστηκαν στο βόρειο τμήμα της Κεφαλληνίας με ένα σεισμικό κενό, της τάξης των 3 χλμ. μεταξύ τους. Η κατανομή των υποκέντρων κυμαίνεται από 0 έως 20 χλμ. Στην πρώτη ομάδα οι μηχανισμοί γένεσης μπορούν να δώσουν δύο διαφορετικές λύσεις,

ανάστροφων ή κανονικών ρηγμάτων, ενώ στη δεύτερη οι μηχανισμοί είναι ανάστροφοι με δεξιόστροφη οριζόντια ολίσθηση. Τέλος, η τρίτη ομάδα προσδιορίστηκε στο δυτικό τμήμα της Λευκάδας, όπου η κατανομή των υποκέντρων κυμαίνεται μεταξύ 0 και 30 χλμ. και οι μηχανισμοί γένεσης παρουσιάζουν ανάστροφες λύσεις με δεξιόστροφη οριζόντια ολίσθηση.

INTRODUCTION

In the summer of 1989, a dense network of 54 portable seismological instruments (smoked paper Sprengnether MEQ-800) and two digital CEIS, equiped with 1hz vertical geophones, was installed in the northwestern part of Greece, Ionian islands, Aitoloacarnania and Epirus, to record the seismicity of the area for a two month period, in order to interprete the stress field of the area.

The network was deployed for an as possible sufficient azimuthal coverage of the seismic area, in order to provide fair hypocentral solutions and reliably determined individual focal mechanisms (Hatzfeld et al., 1990). The smoked paper instruments operated at 60mm/min, yielding a time reading precision of 0.2 and 0.5sec for P and S waves respectively. About 1000 earthquakes were recorded and located by using the HYPO71 routine (Lee and Lahr 1975, Frechet and Glot 1986).

The geodynamics of the Ionian area is complicated as it is situated between the collision and the subduction zones of the European and the African lithospheric plates (Le Pichon and Angelier 1979; Anderson and Jackson 1987; Jackson and McKenzie 1988).

The high level of seismicity in northwestern Greece is characterized by shallow large earthquakes (Papazachos and Comninakis 1982; Makropoulos et al. 1989) with various fault plane solutions (Anderson and Jackson 1987). The northwestern part of this area is characterized by reverse or strike-slip focal mechanisms, while the southern continental part by normal focal mechanisms (McKenzie 1972; 1978; Papazachos et al. 1984; Taymaz et al. 1991; King et al. 1993). East of the area, around the gulf of Corinth, N-S extension dominates (McKenzie 1972; Mercier et al. 1979; Jackson et al. 1982; Armijo et al. 1986).

METHOD AND ANALYSIS

In order to reduce the interposed errors and aquire the relative and absolute uncertainties in the hypocentral solution and the focal mechanisms' construction, we proceeded with the following:

a. By using an initial velocity model (King et al. 1983) and HYPO71, we distinguished and corrected the errors due to arrival time readings and the instrument's internal clock drifting.

b. We determined the value of Vp/Vs ratio, after applying Chatelain's method (1978). For pairs of stations (i,j), we calculated the difference between the P- and S-arrival times (tpj-tpi) and (tsj-tsi). The ratio Vp/Vs=(tsj-tsi)/(tpj-tpi) and the estimated value is 1.812±0.006.

c. To improve the velocity structure, we minimized the rms value (root mean square travel-time residuals) for a group of data with: rms<0.3sec, gap<180°, minimum of 20 P- and S- recorded phases. We chose this particular group of data in order to attain a seismicity representative sample both in location and depth.

Primarily, we located these events using a half-space velocity structure, varying the P-waves' velocity from 4.5 to 6.0 km/sec, while the Vp/Vs ratio was the estimated one, 1.81, in order to determine the first layer velocity. In this case there is a clear minimum in the mean rms at 5.6km/sec for P-waves' velocity. For the second layer at a P-velocity value of 6.1km/sec at a depth of 15km and for the third at 40km depth for a P-velocity of 7.1km/sec. Finally, a "sendimentary" layer down to 4km depth, with a P-velocity of 5.2km/sec, was added to prevent the mislocation of a certain number of superficial events.

d. By using the above mentioned velocity model and the Vp/Vs ratio of 1.81, we calculated the P and S travel-time residuals with HYPO71.

S-wave recordings, by vertical component seismometers, provide poor S-arrival times, thus, we reduced the weight of the S waves by a factor of at least 2 in comparison to P-waves. P- and S- phases were rejected when the absolute values of the calculated residuals were found to be greater than 0.7 and 1.0sec respectively. Rejected were also the events having less than 5P- and 1S- recorded phases and those with a minimum epicentral distance greater than 50km. From the sum of the 1000 events recorded, only 650 satisfied the above mentioned criteria.

SEISMICITY DISTRIBUTION

In figure 1, the location of the 650 microearthquakes recorded during the two month observation period is shown. The overall pattern of the seismic activity follows that of the large events which occured in the area. The events are distributed in dense clusters which are separated by low activity areas.

The northern part of the area shows a high seismicity level. Further south, at the northern part of Amvrakikos Gulf, a low seismicity level area appears. The seismic activity is also observed at the eastern part of Amvrakikos Gulf, where the clusters seem to be, in comparison to the northern part, more separated from one another and concentrated in certain regions. At the SW part, the seismicity appears less pronounced and more concentrated around the Trichonis Lake. The seismicity arrives at a high concentration level in the western part of the islands of Kefallinia and Lefkada.

Deep seismic activity at the NW part of Peloponnesus is observed mainly within the Zakynthos channel (between Zakynthos and Peloponnesus). A remarkable well defined 'aseismic area' is observed between the Ionian islands and the continental part of Greece.

In the present work we attempt to investigate the seismic activity in the areas of Lefkada and Kefallinia in order to interpret the seismotectonic regime revealed. For this, we computed 55 lower hemisphere fault plane solutions using P-wave first motion polarities. The average azimuthal coverage is about

180° for the area of the Ionian islands and so, unfortunately, in some cases we have more than one solutions.

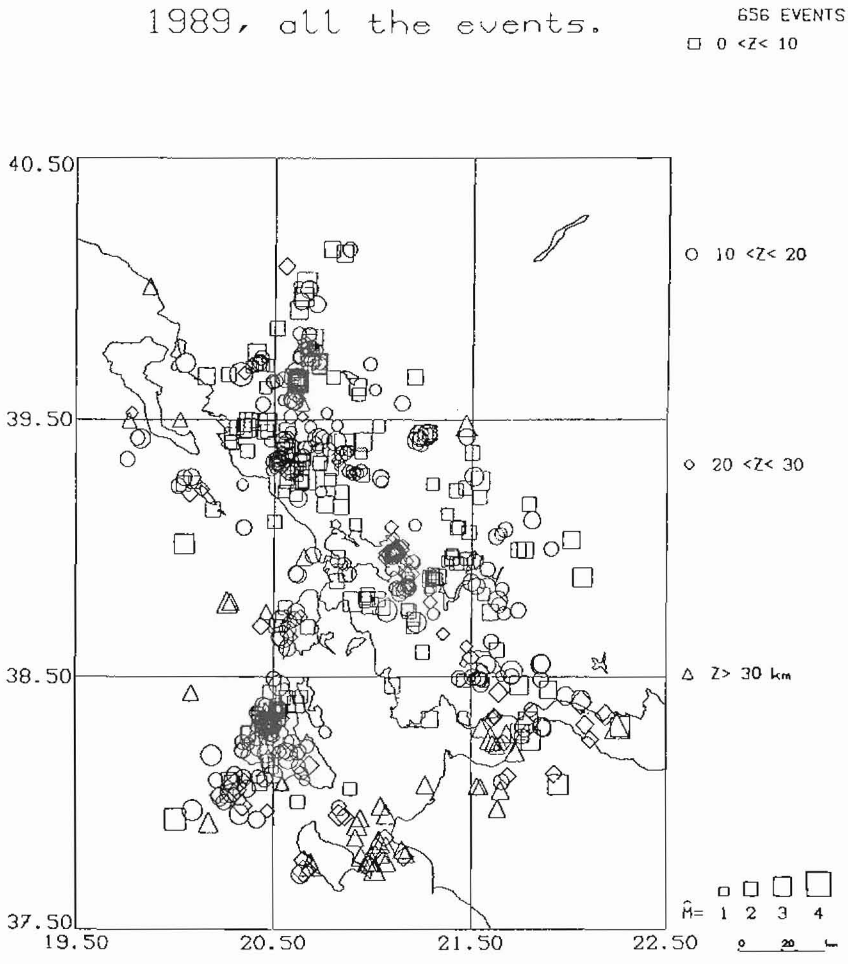


Fig.1. Seismicity map of the area.

LEFKAS DISTRIBUTION

The epicentral distribution and the focal mechanisms of this region are displayed in figure 2. The seismicity is located in the western part of the island and the focal mechanisms indicate reverse right-lateral strike-slip faults with sub-vertical planes. In addition, two normal faults with a strike-slip motion are observed in the western maritime part of the area, near the 2000 m. bathymetric contour. The reverse mechanisms generally display P-axis trending EW and T-axis trending NS.

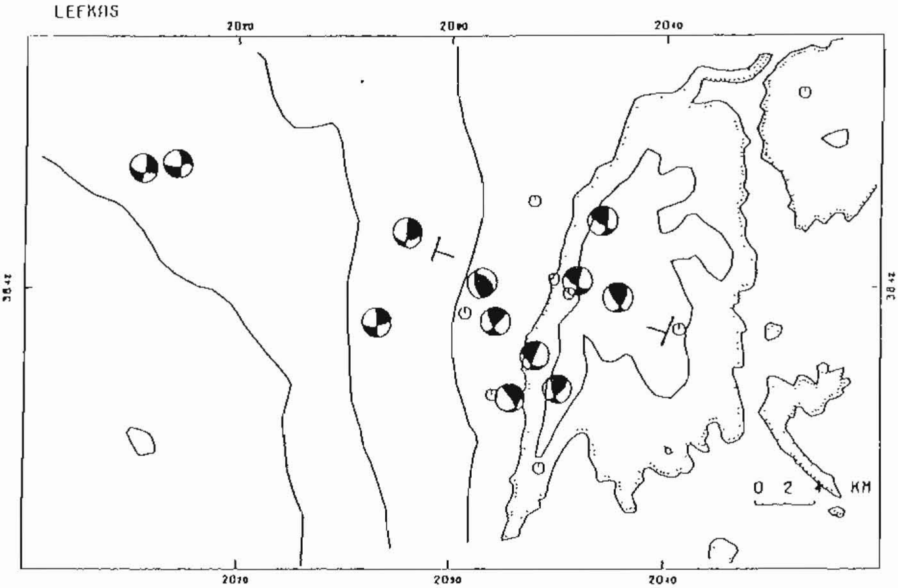


Fig.2. Map of Lefkas island with topographic (600m), bathymetric (600, 1000, 2000, 3000m) contours, epicenters and fault plane solutions.

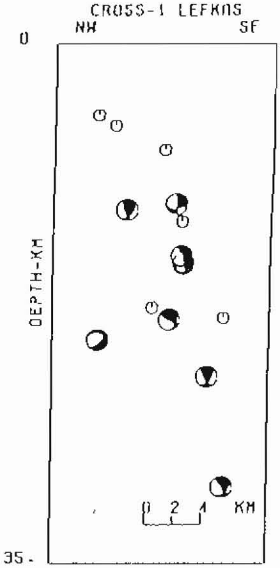


Fig.3. Cross section across Lefkas island (N120°).

A cross section (N120°) perpendicular to the strike of the topography is shown in figure 3. The maximum depth is 30 km with a sub-vertical plane dipping towards the SE. This is in agreement with the SE dipping nodal plane of the reverse focal mechanism and suggests NW-SE compression with a fault plane strike variation from N20° to N40°.

KEFALLINIA DISTRIBUTION

The epicenters, plotted in figure 4 even though they are spread over the entire area, form two well defined clusters in the northern part of the island. The main cluster is located near the village of Zola (called below Zola cluster) and the second one further NE near the village of Assos (called Assos cluster below). Between the two clusters a 'gap' is observed over a distance of about 3 km. Papadimitriou and Papazachos, 1985, show that for a time period from 1963 to 1981 and for earthquakes for M≥4.5, seismic 'gaps' are observed at the northern and southern part of Kefallinia island. In figure 4a, a cross section along the two clusters (N30°), indicates shallow seismicity with a maximum dapth of 20km.

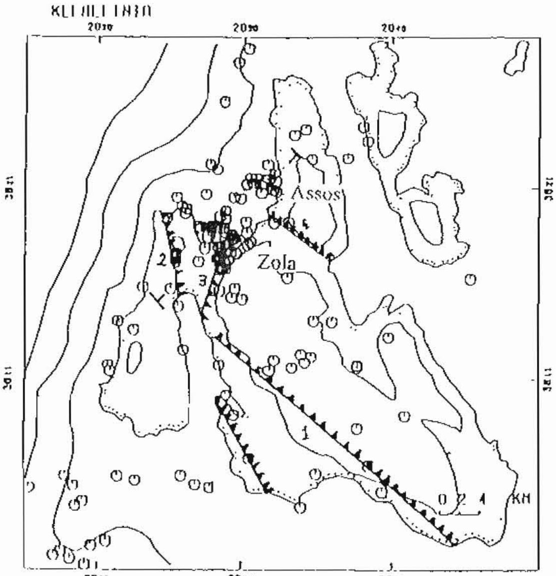


Fig.4. Seismicity map of Kefallinia island, with topographic (600m), bathymetric (600, 1000, 2000m) contours and major tectonic features.

In figures 5a and 5b the lower hemisphere focal mechanisms are displayed. These two figures indicate a completely different tectonic regime. In figure 5a, 41 reverse focal mechanisms are presented, indicating compressive regime in the area. However, three normal fault plane solutions exist on the central-eastern part of the cluster. These different from the overall pattern types of mechanisms, also observed in the Algeria 1980 (Yielding et al. 1989) and Kalamata 1986 (Lyon Caen et al., 1988) earthquakes, were interpreted as a released post-seismic stress. Figure 5b, shows normal focal mechanisms in Zola cluster, indicating an extensional regime.

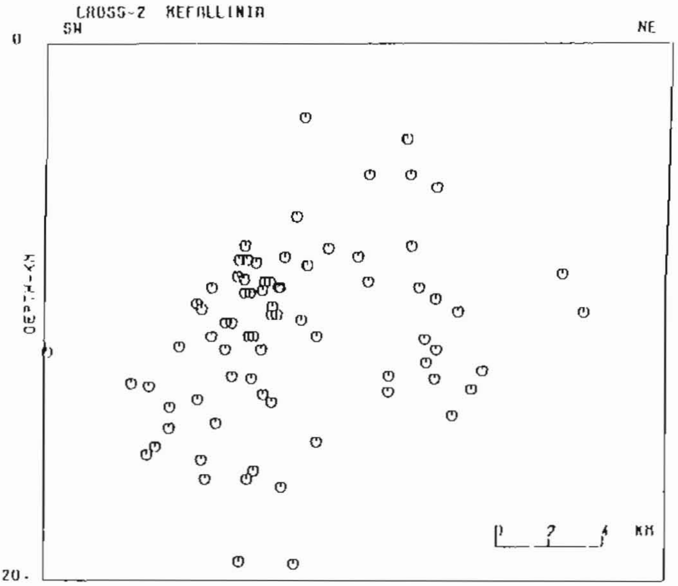
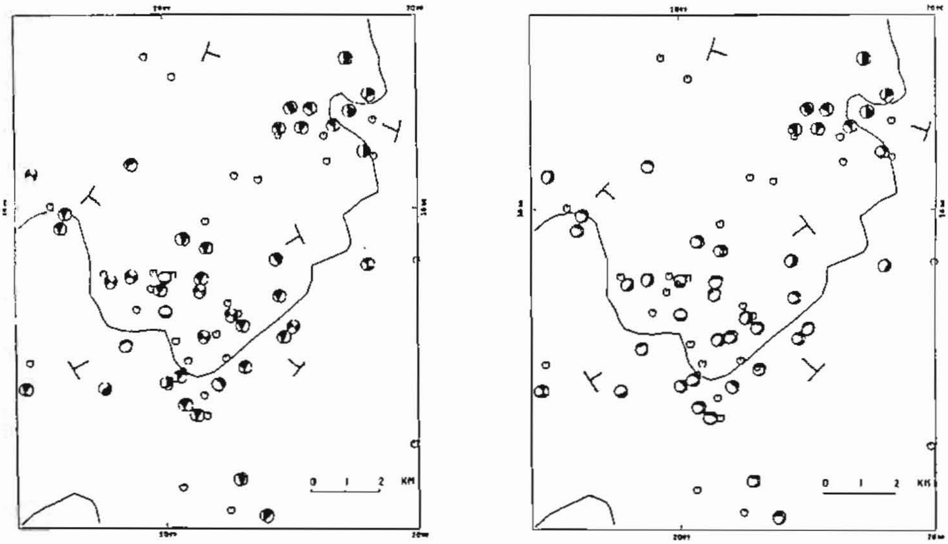


Fig.4a. Cross section along the two clusters (N30°)



(a) (b)

Fig.5. (a) Epicenters and reverse focal mecanisms in north Kefallinia. (b) Epicenters and normal focal mechanisms in north Kefallinia.

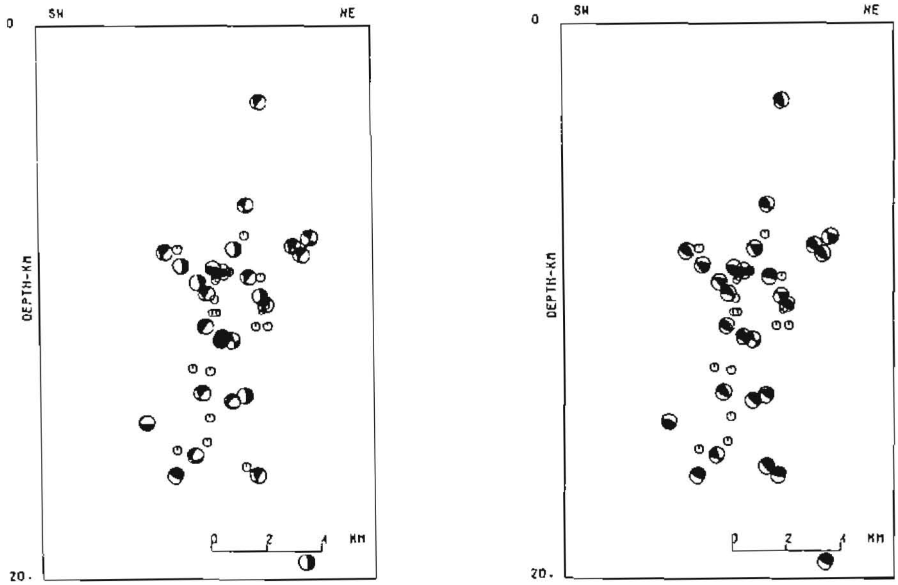


Fig.6. (a) Cross section across Zola cluster (N70°), using reverse focal mechanisms. (b) Cross section across Zola cluster (N70°) using normal focal mechanisms.

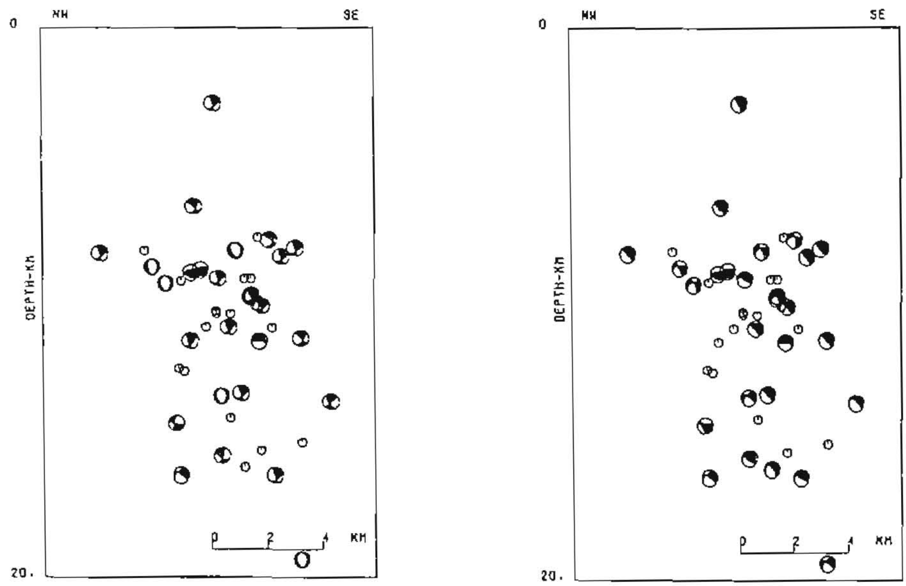


Fig.6. (c) Cross section across Zola cluster (N110°), using reverse focal mechanisms. (d) Cross section across Zola cluster (N110°) using normal focal mechanisms.

In the case of Assos cluster, a single solution of reverse focal mechanisms with a strike-slip component was possible.

Clarifying, we show five cross sections of the area (figure 6). Figure 6a and 6b show the cross section of the Zola cluster across the N70° direction with the reverse and normal fault plane solutions respectively. In the first case (fig.6a), a sub-vertical reverse fault plane striking N340° and dipping to the SW could be defined. This direction could be in agreement with the fault No2 (fig.4) proposed by Sorel (1976), but with an antithetic dipping trend and seismicity located exclusively in the downward part of the fault. In figure 6b, the only way to accept a normal fault solution, is by defining a vertical or a sub-vertical plane with the NE as the downward part. The figures 6c and 6d display cross sections across the Zola cluster in the N110° direction representing reverse and normal fault plane solutions respectively, showing a reverse fault plane dipping to the SE (fig.6c) and a NW dipping normal fault plane (fig.6d).

Finally, figure 6e shows a cross section across Assos cluster in the N 110° direction. In this case, a sub-vertical plane dipping to the SE is defined.

DISCUSSION - CONCLUSIONS

The seismic activity in Lefkas island is characterized by homogeneous reverse strike-slip faults located in a depth range of 0-30 km. This cluster consists of a set of 8 homogeneous focal mechanisms indicating a right-lateral strike-slip motion. The seismicity seems to occur on the fault plane dipping to the SE.

The shallow seismic activity in Kefallinia island, is spread over the entire area and is characterized by a set of heterogeneous focal mechanisms. Sorel (1976) proposed four main reverse faults in the area (fig.4). According to this assumption, four senarios are likely to happen:

The first is that all faults are parallel to the fault No2 (fig. 4). In this case, the reverse fault defined by the Zola cluster indicates antithetic reverse fault, referring to the fault No2.

The second, is a normal fault parallel to the fault No2. This configuration could be in agreement with the normal fault plane solution of the large earthquake, which occured in the western part of the island in 17-9-1972 (Mc Kenzie 1972; 1978; Anderson and Jackson 1987).

The third, is a reverse fault plane which is the northern part of the fault No3 (N20°). This assumption is in agreement with the large earthquake which occured in 17-1-1983 (Scordilis et al. 1985; Papadimitriou 1988; Kiratzi and Langston 1991). The fourth, is a normal fault plane corresponding to the fault No3. The first and the fourth senarios are not consistent with the observed reverse fault (Sorel, 1976) dipping eastwards.

Considering the arguments mentioned above, we conclude that the second or third senarios could be possibly adopted, which means a normal fault striking N340° and dipping NE, or a reverse fault striking N20° and dipping SE, in order to interpret the revealed phenomena. However, more investigation in the specific area is needed to clarify the role of the possibly existing normal faults in the area. A dense local seismic network could help to determine more precicely the sress field of the area.

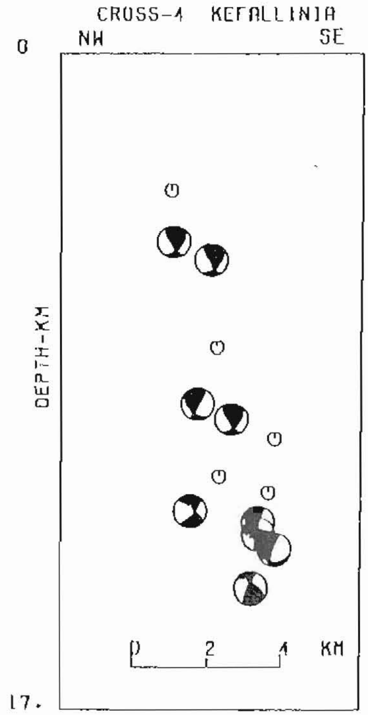


Fig.6. (e) Cross section across Assos cluster (N10°)

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